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Extraordinary numbers of giant squid, *Architeuthis dux*, encountered in Japanese coastal waters of the Sea of Japan from January 2014 to March 2015

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Abstract In total, 57 giant squid, *Architeuthis dux*, were found between January 2014 and March 2015 in Japanese coastal waters in the Sea of Japan. Occurrences were especially high around Sado Island and in Toyama Bay. All of the squid occurred individually, and 28 were found alive. The occurrences were categorized into three groups based on distance from the shore and the depth at which they were found: (1) washed ashore on a beach or found floating at the surface close to a beach (19 individuals); (2) caught in a fixed net set in coastal waters between 50 and 150 m depths (28 individuals); and (3) caught by bottom trawl or bottom gillnet fisheries several kilometers offshore between 200 and 300 m depths (ten individuals). Two size groups were recognized, one ranging between 80 and 160 cm dorsal mantle length (DML) with a mode at 110 cm and another larger than 160 cm DML. The sex ratio in the smaller group was nearly equal and the larger group was comprised of all females. The Sea of Japan was considered to be a large natural trap for giant squid migrating through southwestern Tsushima Strait.

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Introduction

The giant squid is well known as one of the largest marine invertebrates. Not only marine biologists but also the general public have been fascinated by this elusive creature due to their depiction in popular sci-fi novels and movies (Ellis 1998). Since the first species of giant squid, *Architeuthis dux*, was described by Steenstrup in 1857, more than a dozen ill-described and poorly understood *Architeuthis* species have been reported from all over the world (Clarke 1966, 1980; Roper and Boss 1982). In Japanese waters, two nominal species, *A. martensii* (Hilgendorf, 1880) and *A. japonica* Pfeffer, 1912, the latter of which was named based on "Notes on a gigantic cephalopod" by Mitsukuri and Ikeda (1895), were initially described. However, systematic description of *A. martensii* was inadequate for a distinct species; thus, *A. japonica* had been applied to the giant squid in Japanese waters (Sasaki 1916, 1929; Taki 1965). In the early 1980s, Roper and Boss (1982) suggested that the 19 nominal species identified at that time actually comprised only three species, *A. dux* in the northern Atlantic, *A. japonica* in the northern Pacific, and *A. sanctipauli* in the Southern Hemisphere.

Roeleveld and Lipinski (1991) gave detailed descriptions of the external and internal morphology of the giant squid based on three specimens from southern African waters. They recognized that the three specimens were actually a single species but they hesitated to give it a species name. Förch (1998) examined 16 specimens of *Architeuthis* obtained from New Zealand waters and revealed that there was very high inter-individual variability in external and internal morphology. Förch (1998) recommended that the family

Architeuthidae be reduced to a single genus and species, *A. dux*, consistent with the earliest adequate systematic description. Recent genetic study on whole mitochondrial DNA of the giant squid (Winkelmann et al. 2013) demonstrated that there was no detectable phylogenetic structure at the mitochondrial level among 43 samples obtained from oceans all over the world, and the level of nucleotide diversity was exceptionally low. These results strongly support the hypothesis that only one global species, *A. dux*, is valid.

Historically in Japan, giant squid have occasionally washed ashore or been seen floating at the surface of coastal waters of the Sea of Japan, and such sightings have become local news media stories (Nishimura 1968; Honma et al. 1983). Okiyama (1993) accumulated occurrence data between 1941 and 1971, creating a distribution map and monthly occurrences based on 20 records. Findings were scattered along the coasts of Shimane, Tottori, Hyogo, Kyoto, Ishikawa, Toyama, and Niigata Prefectures, as well as Sado Island. Seasonally, the giant squid has appeared in limited numbers in the winter from December to March and has been most abundant in February. Okiyama (1993) observed mass occurrences in the winters of 1974–75 (six records) and 1975–76 (seven records), and suggested that significant recruitment of giant squid occurred twice in these two successive years through the Tsushima Strait. Since 1998, the senior author of the current study has compiled giant squid occurrences in Japanese waters and recorded 19 sightings in the Sea of Japan as of March 2012. On average, one or two individuals appear every 2 years, but an exceptional six individuals were found in the winter of 2006–07 (Kubodera 2013).

During two winter seasons of 2014–2015, 57 individuals were found in Japanese coastal waters of the Sea of Japan. No such mass occurrence of giant squid has ever been reported from any corner of the world. Therefore, we present detailed information of each encounter and the known biological data for each individual. We discuss hypothetical scenarios to explain the mass findings of giant squid in 2014 and 2015 based on the oceanographic characteristics of the Sea of Japan and other factors.

Materials and methods

Whenever an extraordinarily large squid was discovered and brought to the attention of the prefectural fisheries research center, museum, or aquarium, staff were sent to identify and examine the specimen, including measurement and photographs, and to interview the public member(s) who found the squid. The news media was often present and reported the sightings in the local newspapers and on television.

From January 2014 to March 2015, 57 individuals of extra-large squid were discovered along the coastal area of the Sea of Japan, all of which were identified as *A. dux* based on photos and short notes sent by local experts and/or media reports. In addition to those communications, the second author actually visited most of the sites in the western part of the sighting area in 2014 to collect accurate data and specimens, and the third author similarly covered the sites in Niigata Prefecture and Sado Island.

To understand the oceanographic condition of the Sea of Japan, we referred to tri-monthly 10-day mean horizontal water temperature profiles and temperature anomalies at the surface and at depths of 50, 100, and 200 m from December 2013 to March 2015 obtained from the Japan Meteorological Agency (JMA) (http://www.data.jma.go.jp/gmd/kaiyou/data/db/kaikyo/jun/t100_NK.html). In addition, vertical temperature profiles along the PM line (off Echizen Peninsula) and JAY line (from Nihonkai Basin to Yamato Basin) as observed by JMA research vessels in November 2013 were collected (http://www.data.jma.go.jp/gmd/kaiyou/db/vessel_obs/maizuru/index.php?id=2013aut).

Results

The date and location of encounter, situation at finding, depth, type of person who found the squid, person confirming the sighting, and other remarks are summarized in Table 1. The geographic location of each find is plotted in Fig. 1. Biological data of each squid, such as dorsal mantle length (DML; measured dorsally from the tip of the fin to the anteriormost point of the mantle), body length (BL; from the tip of the fin to the longest arm tip), total length (TL; from the tip of the fin to the distal end of the stretched tentacle), body weight (BW), sex, and condition when found are summarized in Table 2. The Appendix presents cases where photos were available.

In total, 57 individuals (24 from January to May 2014 and 33 from September 2014 to March 2015) were found, all of which were confirmed to be giant squid.

Records of findings

Giant squid appeared broadly along the Japanese coast from Yamaguchi to Niigata, and high occurrences were seen around Sado Island in January–May 2014 and in Toyama Bay in September 2014–March 2015, with one exception of the northernmost record from Aomori Prefecture (Fig. 2). In total, 29 individuals out of 57 were actually found in Niigata and Toyama Prefectures.

Giant squid appeared in the winter months and disappeared during the summer months. High occurrences were seen in March–April 2014 and in January–February 2015 (Fig. 3).

Table 1 Summary of giant squids found along Japanese coasts of the Sea of Japan from January 2014 to March 2015

ID no.	Date	Pref.	City	Lat. (N)	Long. (E)	Situation	Finding depth (m)	C.G.	Discovered by	Reported by	Remarks
A-1	2014/1/4	Toyama	Off Himi-shi	36.54	137.04	Fixed net for Japanese amberjack	<100	2	Fisherman	Fuji News Network (1/4)	Landing on the Himi fishing port
A-2	2014/1/8	Niigata	1 km off Shirose, Sado Is.	38.07	138.27	Fixed net	70	2	Fisherman	M. Higuchi[a]	Video footage
A-3	2014/1/19	Niigata	Arahama Beach, Kashiwazaki-shi	37.24	138.34	Stranded	On beach	1	Neighborhood	K. Minowa[b]	
A-4	2014/1/20	Tottori	30 km off Tottori-shi	35.52	134.11	Bottom gillnets for flounder	236	3	Fisherman	T. Wada	
A-5	2014/2/10	Niigata	2 km off Shirose, Sado Is.	38.08	138.30	Bottom gillnets for anglerfish	<274	3	Fisherman	M. Higuchi[a]	Examined by Higuchi and his co-worker
A-6	2014/2/13	Niigata	Off Washizaki, Sado Is.	38.19	138.33	Fixed net	<159	2		S. Abe[a]	
A-7	2014/2/25	Hyogo	Off Moroyori, Shinonsen-cho	35.38	134.25	Floating	Surface	1	Fisherman	T. Yamaguchi[c]	Landing on the Moroyori fishing port
A-8	2014/3/2	Niigata	On the shore of Shiidomari, Sado Is.	38.08	138.29	Stranded	On beach	1		S. Abe[a]	
A-9	2014/3/4	Tottori	On the rocky shore of Akasaki, Kotoura-cho	35.31	133.37	Stranded	On beach	1		T. Wada	
A-10	2014/3/5	Hyogo	Off Amarube, Kasumi-ku, Kami-cho	30.53	134.34	Bottom trawl for firefly squid	<223	3	Fisherman	T. Wada	Displayed at the Kinosaki Marine World
A-11	2014/3/16	Niigata	Benten-hama, Itoigawa-shi	37.04	137.56	Stranded	On beach	1		M. Baba[d]	
A-12	2014/3/24	Yamaguchi	30 km off Mishima, Hagi-shi	35.08	131.10	Bottom trawl	<121	3	Fisherman	T. Fujita[e]	Displayed at the Shimane Aquarium
A-13	2014/3/26	Niigata	Off Hayoshi, Sado Is.	38.07	138.26	Fixed net	<206	2	Fisherman	M. Higuchi[a]	Specimen of NSMT
A-14	2014/3/26	Niigata	In the port of Ryotsu, Sado Is.	38.04	138.26	Floating	Surface	1	Fisherman	M. Higuchi[a]	Specimen of NSMT
A-15	2014/4/7	Toyama	1 km off Yokataminatomachi, Toyama-shi	36.46	137.15	Fixed net for firefly squid	<100	2	Fisherman	The Sankei Shimbun (4/7)	
A-16	2014/4/8	Toyama	1.5 km off Imizu-shi	36.48	137.07	Bottom trawl for Japanese glass shrimp	<300	3	Fisherman	The Sankei Shimbun (4/8)	Landing on the Shin-minato fishing port
A-17	2014/4/9	Hyogo	West of Peninsula Nekozaki, Toyooka-shi	35.40	134.45	Floating	Surface	1	Angler	T. Wada	Kinosaki Marine World
A-18	2014/4/12	Shimane	Off Aika-cho, Matsue-shi	35.30	132.54	Stranded	On beach	1	Angler	The Shikoku Shimbun (4/12)	
A-19	2014/4/12	Niigata	Off Waki, Sadi Is.	38.09	138.29	Fixed net	<200	2		M. Higuchi[a]	
A-20	2014/4/13	Tottori	At the mouth of Yoshida river, Makidani, Iwami-cho	35.35	134.2	Stranded	On beach	1		T. Wada	
A-21	2014/4/18	Ishikawa	2 km off Ohtomari-machi, Nanao-shi	36.58	137.05	Fixed net for Japanese amberjack	<94	2		The Hokkoku Shimbun (4/19)	Displayed at the supermarket
A-22	2014/4/27	Ishikawa	Off Furai port, Saikai, Sika-machi	37.07	136.39	Fixed net	<57	2	Fisherman	S. Ikeguchi[f]	Dissected at the Notojima Seaside Park
A-23	2014/5/6	Kyoto	North off Kyotango-cho, Kyotango-shi	35.52	135.05	Bottom trawl	<218	3	Fisherman	Y. Ueno[g]	Discarded
A-24	2014/5/7	Niigata	Off Awashima Is, Awashimaura-mura	38.26	139.17	Bottom trawl	<79	3		Nigataken Suikaiken Dayori (No. 30)	
B-1	2014/9/4	Shimane	Off Hamada-shi	35.02	131.39	Fixed net?	120	2	Fisherman	T. Fujita[e]	Exhibited at Shimane Aquarium

Table 1 (continued)

ID no.	Date	Pref.	City	Lat. (N)	Long. (E)	Situation	Finding depth (m)	C.G.	Discovered by	Reported by	Remarks
B-2	2014/10/22	Fukui	900 m off Komeno, Echizen-cho	35.53	135.58	Fixed net	65	2	Fisherman	S. Sasai[h]	Exhibited at Echizen Matsushima Aquarium for four days
B-3	2014/11/8	Niigata	1 km pff Waki, Sado Is.	38.09	138.29	Fixed net	<200	2	Fisherman	The Asahi Shimbun (11/11)	Displayed at the Fish Festival
B-4	2014/11/20	Tottori	East off Okinoshima	36.16	133.4	Purse seine	–	3	Fisherman	K. Ichisawa[i]	Landing on the Sakai port
B-5	2014/11/24	Fukui	Around Ongami-jima, Wakasa-cho	35.38	135.47	Fixed net?	<60	2	Fisherman	The Chunichi Shimbun (11/24)	Examined and exhibited at Echizen Matsushima Aquarium
B-6	2014/11/24	Kyoto	1 km off Tangocho-taiza, Kyotango-shi	35.45	135.04	Floating at surface	Surface	1	Angler	Y. Ueno[g]	Left undisturbed
B-7	2014/11/27	Toyama	3.3 km off Yahatacho, Imizu-shi	36.49	137.07	Bottom trawl for glass shrimp	330	3	Fisherman	The Chunichi Shimbun (11/27)	Served in an event after hard-cured
B-8	2014/12/9	Hyogo	Kirihama beach, Takenocho, Toyooka-shi	35.39	134.44	Stranded	On beach	1	Local people	T. Wada[e]	Specimen of the Museum of Nature and Human Activities, Hyogo
B-9	2014/12/23	Kyoto	Off Ineura, Ine-cho, Yozagun	35.38	135.17	Fixed net	<60	2	Fisherman	Y. Ueno[g]	Exhibited at the Kyoto Aquarium for two days
B-10	2014/12/24	Kyoto	Honjyo beach, Ine-cho, Yozagun	35.43	135.16	Stranded	On beach	1	Local people	Y. Ueno[g]	Recovered by Kyoto Prefectural Agriculture, Forestry and Fisheries Technology Center
B-11	2014/12/28	Fukui	600 m off Tomari, Obama-shi	35.32	135.42	Fixed net	<20	2	Fisherman	Fukui Shimbun (12/28)	Disposal in the ocean
B-12	2014/12/31	Toyama	2 km off Toyama-shi	36.47	137.13	Fixed net	<100	2	Fisherman	Fuji News Network (12/31)	Video footage
B-13	2015/1/6	Tottori	Oobaneo beach, Iwami-cho	35.36	134.2	Stranded	On beach	1	Local people	Y. Kiyosue[f]	
B-14	2015/1/13	Aomori	South of Tsubakiyama, Henashi, Fukaura-machi	40.35	139.51	Stranded	On beach	1	Fisherman	E. Koganezaki[k]	Empty stomach
B-15	2015/1/15	Toyama	500 m off Iino, Nyuzen-cho	36.56	137.25	Fixed net for amberjack	50–60	2	Fisherman	M. Kanbayashi[l]	
B-16	2015/1/19	Toyama	2 km off Shinminato, Hachiman-machi, Imizu-shi	36.47	137.06	Fixed net	60	2	Fisherman	The Toyama Shimbun (1/20)	Exhibited at Michinoeki Shinminato
B-17	2015/1/19	Toyama	2 km off Yokata-fishing port, Toyama-shi	36.46	137.11	Fixed net	90	2	Fisherman	Fuji News Network (1/19)	Video footage
B-18	2015/1/22	Toyama	2 km off Iwase, Toyama-shi	36.47	137.14	Fixed net for amberjack	–	2	Fisherman	The Kitanippon Shimbun (1/23)	Caught with a school of Japanese common squid
B-19	2015/1/29	Toyama	Off Shinminato, Hachiman-machi, Imizu-shi	36.47	137.07	Fixed net	–	2	Fisherman	The Kitanippon Shimbun (1/30)	Below individual was found nearby the fixed net on the same day
B-20	2015/1/29	Toyama	Off Shinminato, Hachiman-machi, Imizu-shi	36.47	137.07	Fixed net	–	2	Fisherman	The Kitanippon Shimbun (1/30)	Above individual was found nearby the fixed net on the same day
B-21	2015/2/3	Toyama	2 km off Yokata-fishing port, Toyama-shi	36.46	137.11	Fixed net	78.4	2	Fisherman	Fuji News Network (2/4)	Video footage
B-22	2015/2/4	Toyama	1 km off Aoshima, Uozu-shi	36.5	137.23	Fixed net	–	2	Fisherman	Toyama Television Broadcasting (2/4)	

Table 1 (continued)

ID no.	Date	Pref.	City	Lat. (N)	Long. (E)	Situation	Finding depth (m)	C.G.	Discovered by	Reported by	Remarks
B-23	2015/2/6	Ishikawa	500 m off Kodomari, Misakimachi, Suzu-shi	37.26	137.22	Fixed net	40	2	Fisherman	The Hokkoku Shimbun (2/6)	Was released
B-24	2015/2/7	Ishikawa	2 km off Iorimachi, Nanao-shi	37.02	137.04	Fixed net	–	2	Fisherman	The Yomiuri Shimbun (2/8)	Exhibited in Notojima Seaside Park
B-25	2015/2/7	Ishikawa	2 km off Shichimi, Noto-cho	37.15	137.07	Fixed net	–	2	Fisherman	The Yomiuri Shimbun (2/8)	Exhibited in Notojima Seaside Park
B-26	2015/2/16	Niigata	1.5 km off Shirouse, Sado Is.	38.07	138.28	Fixed net	–	2	Fisherman	The Niigata Nippo (2/16)	Exhibited at a local supermarket
B-27	2015/2/17	Fukui	Gunkan rock, Gumizaki-cho, Fukui-shi	36.02	136	Stranded	At rock reef	1	Local people	S. Sasai[h]	Dissected and discarded
B-28	2015/2/18	Yamaguchi	Tsunoshima, Toyokita-cho, Shimonoseki-shi	34.21	130.51	Stranded	At rock reef	1	Tourist	The Yamaguchi Shimbun (2/19)	Exhibited at the Shimonoseki Kaikyokan during a period of the summer holiday
B-29	2015/2/23	Toyama	Ferry pier Koshinokata-machi, Imizushi	36.46	137.06	Floating	1	1	A harbor official	Tulip-tv (2/23)	Swam away
B-30	2015/3/1	Toyama	1–3 km off Namerikawa-shi	36.47	137.19	Fixed net for firefly squid	–	2	Fisherman	Toyama Television Broadcasting (3/1)	Disposal in the oceans
B-31	2015/3/1	Fukui	Off Takasu, Hamaju-cho, Fukui-shi	36.07	–	Bottom trawl	200	3	Fisherman	S. Sasai[h]	
B-32	2015/3/10	Niigata	Osaki beach, Nishiyama-cho, Kashiwazaki-shi	37.29	138.38	Stranded	On beach	1	Local people	K. Minowa[b]	
B-33	2015/3/26	Niigata	Yoneyama beach, Kashiwazaki-shi	37.18	138.25	Stranded	On beach	1	Local people	M. Baba[d]	Swept out to sea

C.G. Categorized group: 1 = washed ashore or floating; 2 = fixed net, shallow; 3 = bottom trawl, deep

[a] Niigata Prefectural Fisheries and Marine Institute

[b] Kashiwazaki City Museum

[c] NHK (Japan Broadcasting Corporation)

[d] Joetsu Aquarium Museum

[e] Shimane Aquarium

[f] Notojima Seaside Park

[g] Fisheries Technology Department; Kyoto Prefectural Agriculture, Forestry and Fisheries Technology Center

[h] Echizen Matsushima Aquarium

[i] Tottori Prefectural Museum

[j] Museum of Nature and Human Activities, Hyogo

[k] Ajigasawa Fisheries Office

[l] Kitanihon Broadcasting

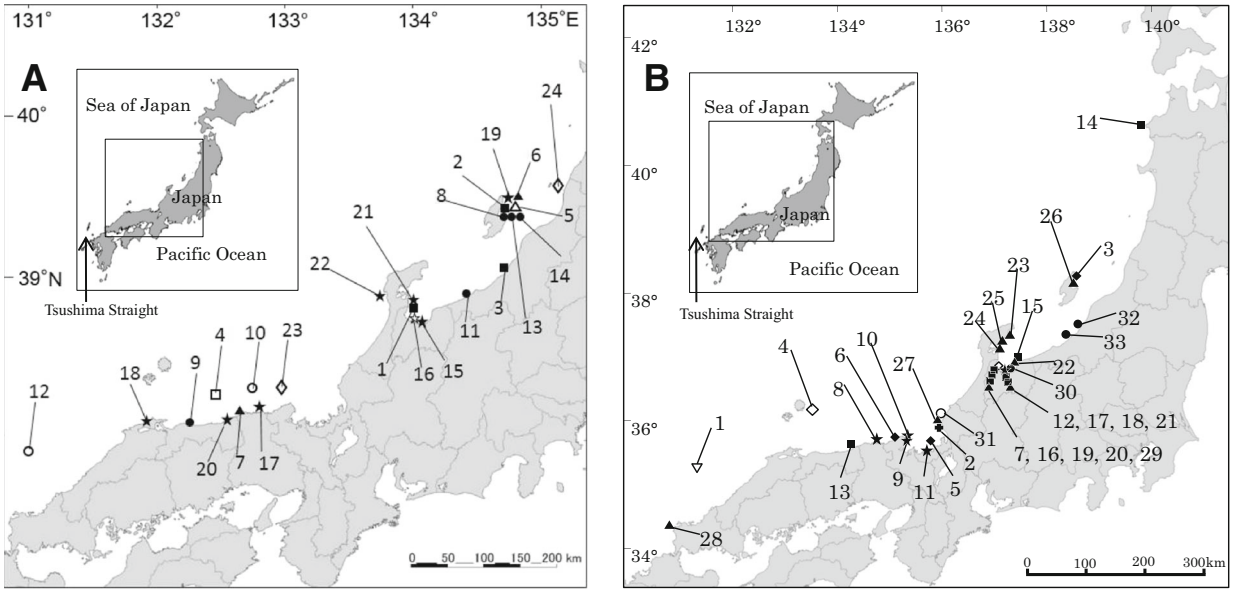

Fig. 1 Positions at which giant squid were found during January–May 2014 (**a**) and September 2014–March 2015 (**b**). The numbers correspond to the ID numbers in Table 1. **a** ■: January 2014, ▲: February 2014, ●: March 2014, ★: April 2014, ◆: May 2014. **b** ▼: September 2014, ✚: October 2014, ◆: November 2014, ★: December 2014, ■: January 2015, ▲: February 2015, ●: March 2015. The *solid symbols* indicate individuals stranded on beaches, drifting at the surface, and/or found in fixed nets, while the *open symbols* indicate individuals caught by bottom trawl nets or bottom gillnets

Situation at finding

Among the 57 cases, 28 individuals were found alive, 22 were found dead, and this information was unavailable for seven (Fig. 4). All specimens were grouped according to distance from the shore and depth at which they were found: (1) individual washed ashore onto a beach or found floating at the surface close to a beach (19 cases); (2) individual was caught by a fixed net set in coastal waters at depths between 50 and 150 m (28 cases); (3) individual was caught by bottom trawl or bottom gillnet fisheries operating several kilometers off shore at depths between 200 and 300 m (ten cases) (Fig. 5). Half of these were trapped in fixed nets set in coastal waters shallower than 150 m depth (Table 1)).

Biological information

The DML of 36 of the 57 individuals was measured, the BL was measured for 31, and the TL, including tentacles, was measured for 20. BW was roughly measured in 20 individuals and sex was determined in 19 individuals (Table 2). DML, BL, TL, and BW ranged between 84–196 cm, 270–446 cm, 260–637 cm, and 25.2–ca. 200 kg, respectively. The sex ratio was eight females to five males. The measurements recorded for each specimen varied, so the summary that follows also varies in what can be summarized. The smallest female was 84 cm DML, 448 cm TL, and 33.2 kg BW, and the smallest male was 91 cm DML, 394 cm TL, and 25.2 kg BW. The largest female was 196 cm DML, 446 cm BL, and ca. 200 kg BW, and the largest male was 150 cm DML, 350 cm BL, and BW unknown. Two size groups were recognized, one with a DML of 80–160 cm with a mode at 110 cm and another with a DML of >160 cm with a mode at 170 cm (Fig. 6). The former group had a nearly equal sex ratio. The latter group was all females except for unexamined individuals.

Discussion

The Sea of Japan is a 978,000-km^2 marginal sea, located in the western periphery of the North Pacific. It is bordered by the Eurasian continent to the west and the Japanese archipelago to the east, and is connected to the Okhotsk Sea through the narrow Soya Strait to the north, to the North Pacific through Tsugaru Strait in the east, and to the East China Sea through the narrow Tsushima Strait to the south. The average depth is about 1667 m and its deepest point is 3742 m. The warm Tsushima Current flows into the Sea of Japan through Tsushima Strait from the south and runs along the Japanese coast to the north and flows out through Tsugaru Strait into the North Pacific and through Soya Strait into the Okhotsk Sea. Due to the narrow (ca. 200-km width) and shallow (90–130-m depth) geography of Tsushima Strait, limited water circulation occurs in the upper layers shallower than ca. 300 m depth. Deeper than that, so-called “Japan Sea Proper Water”, which is characterized by extremely cold (0–1 °C) and high salinity (34.1 PSU) water, is distributed throughout the Sea of Japan (http://www.jma-net.go.jp/jsmarine/japansea.html).

Giant squid are estimated to live in mesopelagic waters of temperate open oceans (Clarke 1966; Roper and Boss 1982).

Table 2 Biological date of the giant squids summarized in Table 1

ID no.	DML (cm)	BL (cm)	TL (cm)	BW (kg)	Sex	Condition	Tentacle	Remarks
A-1	–	350	–	–	–	Dead	Absent	
A-2	187	406	–	163	F	Alive	Absent	
A-3	–	–	–	–	–	Dead	Absent	Only head and arms. Arm length 1.2 m
A-4	170	340	–	–	F	Alive	Absent	
A-5	136	305	–	ca. 100	M	Alive	Absent	
A-6	91	–	394	25.2	M	Alive	Present	
A-7	–	410	–	ca. 200	F	Alive	Absent	
A-8	135	285	–	–	F	Dead	Absent	
A-9	120.8	–	462.5	–	–	Dead	–	
A-10	123	–	430	50	–	Dead	Present	
A-11	196	446	–	ca. 200	F	Dead	Absent	
A-12	116	270	570	–	M	–	Present	
A-13	84	–	448	33.2	F	Alive	Present	
A-14	110	–	435	37.7	M	Alive	Present	
A-15	150	350	–	–	M	Alive	Absent	
A-16	110	275	510	–	–	Alive	Present	
A-17	112	–	594	–	–	Dead	Present	
A-18	–	–	ca. 500	–	–	Alive	–	
A-19	ca. 100	–	–	–	–	–	–	
A-20	121.5	–	637	–	F	Dead	Present	
A-21	–	–	480	30	–	Dead	Present	
A-22	111	289	565	60	F	Alive	Present	
A-23	ca. 100	–	–	–	–	Dead	–	
A-24	92	–	420	–	–	–	Present	
B1	140	314	–	–	M	–	Absent	
B-2	117	264	288	ca. 40	M	Dead	Absent	
B-3	–	–	260	–	–	–	Present	
B-4	183.5	–	–	130	F	Dead	Absent	Head and mantle separated
B-5	137	–	740	ca. 60	–	Alive	Present	Good condition
B-6	–	–	–	–	–	Dead	Absent	Only head and arms. Arm length 1.2 m
B-7	155	–	630	–	–	Alive	Present	
B-8	–	350	–	ca. 100	–	Dead	Absent	
B-9	–	320	–	ca. 70	–	Alive	Absent	
B-10	178	–	507	ca. 100	–	Dead	One side only	
B-11	–	ca. 300	–	–	–	Alive	Absent	
B-12	–	–	–	–	–	Alive	Absent	
B-13	180.5	355	–	–	–	Dead	Absent	
B-14	127	–	–	–	M	Dead	Absent	
B-15	–	420	–	–	–	–	Absent	
B-16	ca. 200	–	ca. 600	ca. 200	–	Alive	–	
B-17	–	ca. 300	–	–	–	Alive	–	
B-18	ca. 200	–	ca. 600	–	–	Alive	Present	
B-19	170	ca. 400	–	–	–	Alive	Absent	
B-20	–	–	–	–	–	Alive	–	
B-21	ca. 200	ca. 400	–	–	–	Alive	Absent	
B-22	–	ca. 400	–	–	–	–	–	
B-23	–	335	–	–	–	Alive	–	
B-24	–	420	–	ca. 200	–	Alive	Absent	
B-25	–	360	–	ca. 150	–	Alive	Absent	
B-26	–	415	–	–	–	Alive	Absent	
B-27	175	377	–	–	F	Dead	Absent	
B-28	–	286	–	65.5	–	Dead	Absent	
B-29	–	250-300	–	–	–	Alive	–	
B-30	ca. 200	–	–	–	–	Alive	–	
B-31	177	376	–	–	F	Dead	Absent	Empty stomach
B-32	161	327	–	–	–	Dead	Absent	
B-33	190	360	–	–	–	Dead	Absent	

Kubodera and Mori (2005) revealed that a giant squid off the Ogasawara Islands in the North Pacific appeared at 900 m depth and swam up to 600 m to escape from a jig on which its tentacle was hooked. They reported that the water temperatures at 900 and 600 m depth were about 4 and 6 °C, respectively. This evidence suggests that giant squid in the Sea of Japan might not be permanent residents but, rather, migrants from the south, passing through bottom layer waters of the Tsushima Strait when the water temperature there decreases to below ca. 6 °C in mid-winter to early spring. Once they have traveled into the Sea of Japan, water temperatures in the deep layer are too cold and they probably move through the water column to the more suitable temperature zone between the warm surface layer and the cold Japan Sea Proper Water during summer to fall.

Okiyama (1993) suggested a possible reason for why giant squid have been occasionally found dead on beaches or caught in fixed nets set in Japanese coastal waters of the Sea of Japan during winter to early spring. At the beginning of winter, the surface water is cooling down

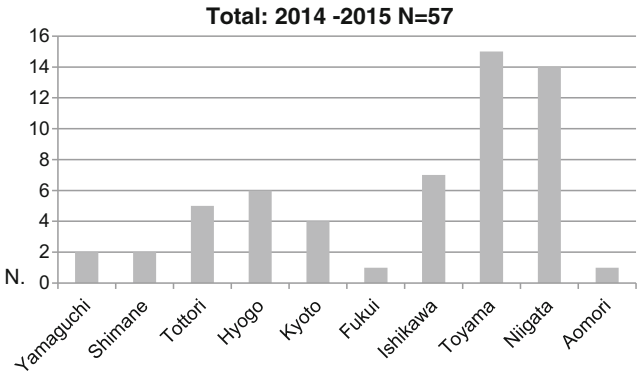

Fig. 2 Regional occurrences of giant squid along the Japanese coast of the Sea of Japan from Yamaguchi Prefecture to Aomori Prefecture (i.e., south to north)

from the northern peripheries along the continental coasts and the cold surface water at 0–1 °C subsides into deeper stratum, which is the origin of the Japan Sea Proper Water. Cold water subsidence commences from the north and gradually extends to the south as winter progresses. This cold water movement might reduce the suitable temperature habitat of the giant squid both horizontally and vertically. They are forced to move southward and to shallower depths. Some individuals would be weakened by exposure to extremely cold waters and then transported by eddies of the Tsushima Current and strong northwesterly seasonal winds, which would result in them coming closer to Japanese coastal waters and explain them being trapped in fixed nets and/or becoming stranded on beaches along the Japanese coast.

Although this is one possible explanation for the occurrence of giant squid in Japanese coastal waters of the Sea of Japan, the unusual mass findings of giant squid in 2014 and 2015 are likely due to a different mechanism. Judging from 10-day and monthly mean water temperature anomalies at the surface and 100 m depths during the winter seasons of 2014 and 2015, the water temperatures at these depths were apparently lower in both years than usual, especially in January 2014 and February 2015. Prominent large-scale cold water masses that developed in the middle layer of the central portion of the Sea of Japan in 2014 and 2015 might have worked strongly to carry the giant squid to the surface layer and towards the Japanese coast. In addition, although there were few records of giant squid during 2008–2013 (Kubodera, personal observation), it is possible that a number of giant squid entered the Sea of Japan during these years and survived there until 2014.

One of the important biological findings of giant squid deduced from the recent mass findings is the bimodal size frequency distribution (80–160 cm DML with a mode at 110 cm and 160–190 cm DML with a mode at 170 cm DML) in winter season. The smaller group had a nearly even sex ratio and the larger group was comprised entirely of females. Wada et al. (2015) recently reported that two young giant squid measuring 33 cm DML were caught by purse seine net in the southwestern Sea of Japan on June 14, 2013. Assuming that a young giant squid measuring 33 cm DML in June grows to 110 cm DML by January, the monthly growth rate would be ca. 11 cm DML. This value represents very rapid growth and an inclination towards an S-growth curve, with lower growth rates in earlier and later life stages. The overall size composition of giant squid in the Sea of Japan suggests a longevity of 2 years for males and 3 years for females.

Roper and Shea (2013) reviewed current knowledge on the taxonomy and systematics, distribution, population size, habitat use, age and growth, predation and feeding, reproduction and life cycles, and functional morphology of giant squid and found wide gaps. The present mass findings of 57 individuals within a relatively short period of time, two winter seasons between 2014 and 2015, and

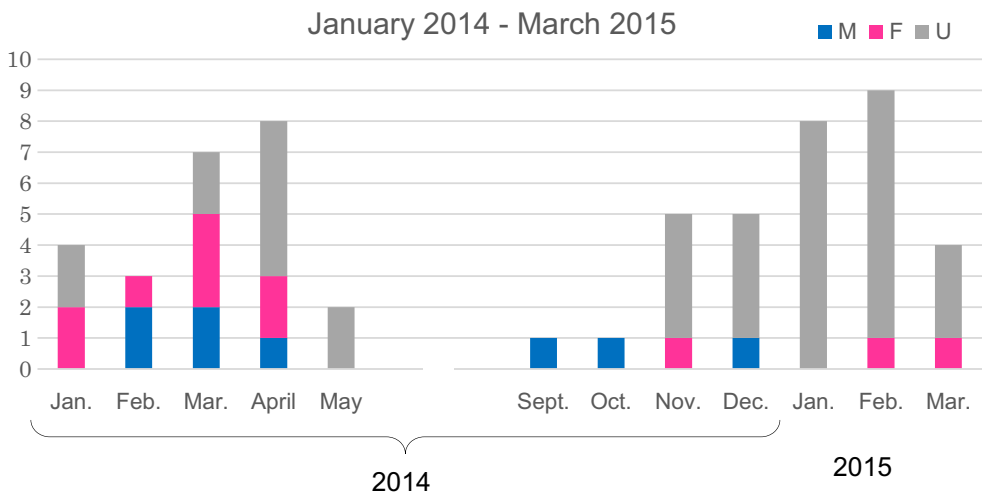

Fig. 3 Monthly occurrences of giant squid along the Japanese coast of the Sea of Japan from January to March 2015 by sex (*blue*: male, *pink*: female, *gray*: undetermined)

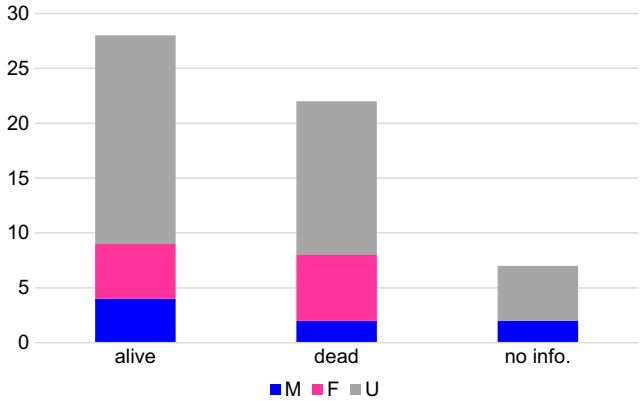

Fig. 4 Frequencies of individuals found dead and alive by sex: *blue*: male (*M*), *pink*: female (*F*), *gray*: undetermined (U)

a restricted area of Japanese coast of the Sea of Japan have greatly increased the available information necessary to understand the natural history of giant squid.

Roper et al. (2015) investigated records of giant squid that were discovered in the western North Atlantic Ocean between Newfoundland and the Gulf of Mexico and provided detailed information on 28 individuals found during 1952–2011. They recognized a general upwards trend in the number of sightings in the 1990s and 2000s, reflecting the increased scientific awareness and growing popular interest in giant squid. In Japan, we had two large events concerning giant squid in 2013. One was a TV program airing on Japan's national public broadcasting organization, NHK, in January, which broadcast the first encounter with a live giant squid using a manned submersible in the deep sea off the Ogasawara Islands. The other was a special exhibition entitled "The Deep" held at the National Museum of Nature and Science in Tokyo from July to September, in which a preserved giant squid specimen as well as videos of live giant squid filmed for the first time were introduced. These two events made Japanese people, especially the younger generations, become more interested in the giant squid. Such a boom in attention directed towards giant squid and other deep-sea creatures likely increases the awareness of

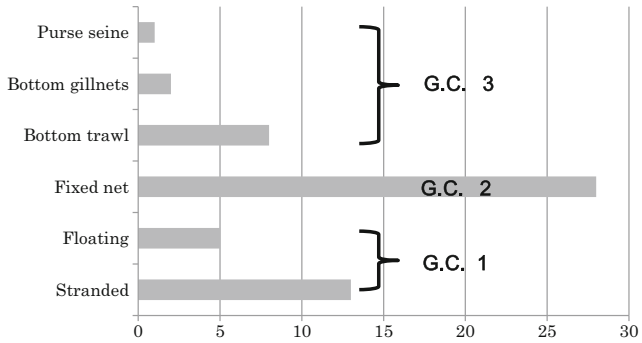

Fig. 5 Frequency of individuals found stranded on a beach, floating at the surface, caught in a fixed net, caught by a bottom trawl net, caught in a bottom gillnet, and caught by purse seine, categorized into three groups based on distance from the shore and depth at which they were found

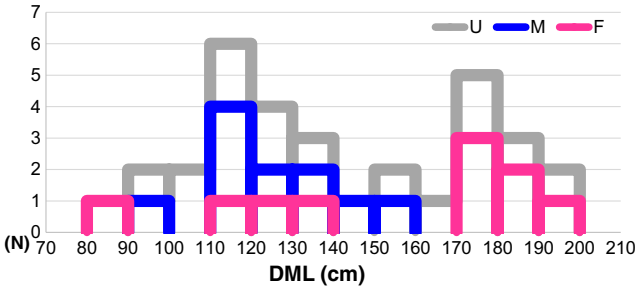

Fig. 6 Size (dorsal mantle length in cm) frequency distribution of giant squids ($N = 32$) found in the coastal waters of the Sea of Japan during January 2014 to March 2015

giant squid among people in coastal regions and encourages them to alert the media and local experts to any findings.

We also suggest that the Sea of Japan may work as a large natural trap for giant squid migrating from the south during early spring. Their distribution spreads widely into the mid-layers, which are within their suitable water temperature zone, and they continue to grow during summer and fall. In winter, the oceanographic characteristics of the Sea of Japan may compel giant squid to move southward and to shallower surface waters, where the coastal eddy of the Tsushima Current and strong westward seasonal winds may carry them to Japanese coastal waters, where they become entangled in fixed nets or stranded on beaches. For future "giant squid" research, the Japanese coasts of the Sea of Japan during the winter months would be the most suitable area to encounter live giant squid.

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